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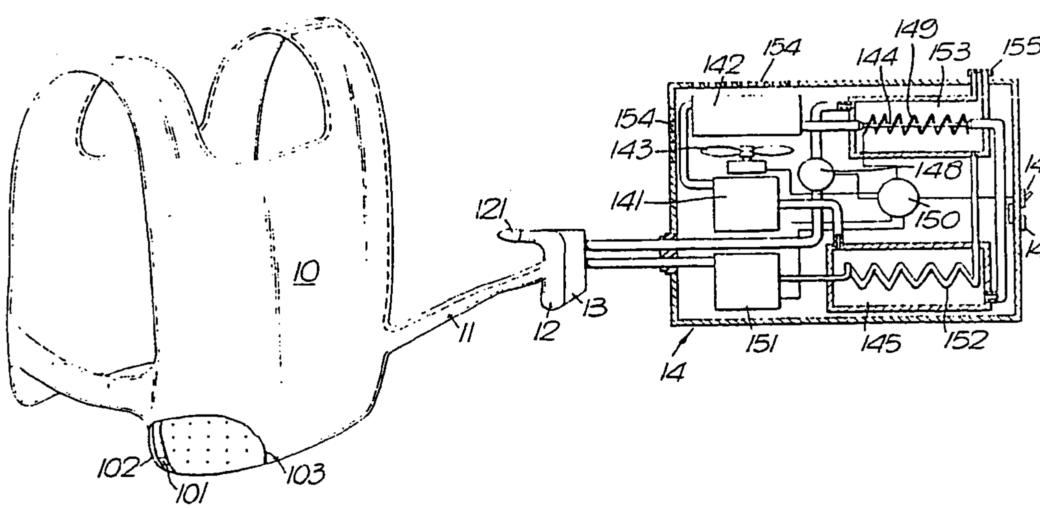
(54) Heat pipe assemblies

(57) A heat pipe assembly comprises a first heat exchanger of heat pipe form, e.g. a thermal conditioning garment (10), and a thermal reservoir (14), which may include a heat pump (141, 142, 144, 145). Means are provided for evacuating at least the first exchanger, which is connected to the reservoir by means of a releasable coupling.

Fig.1.



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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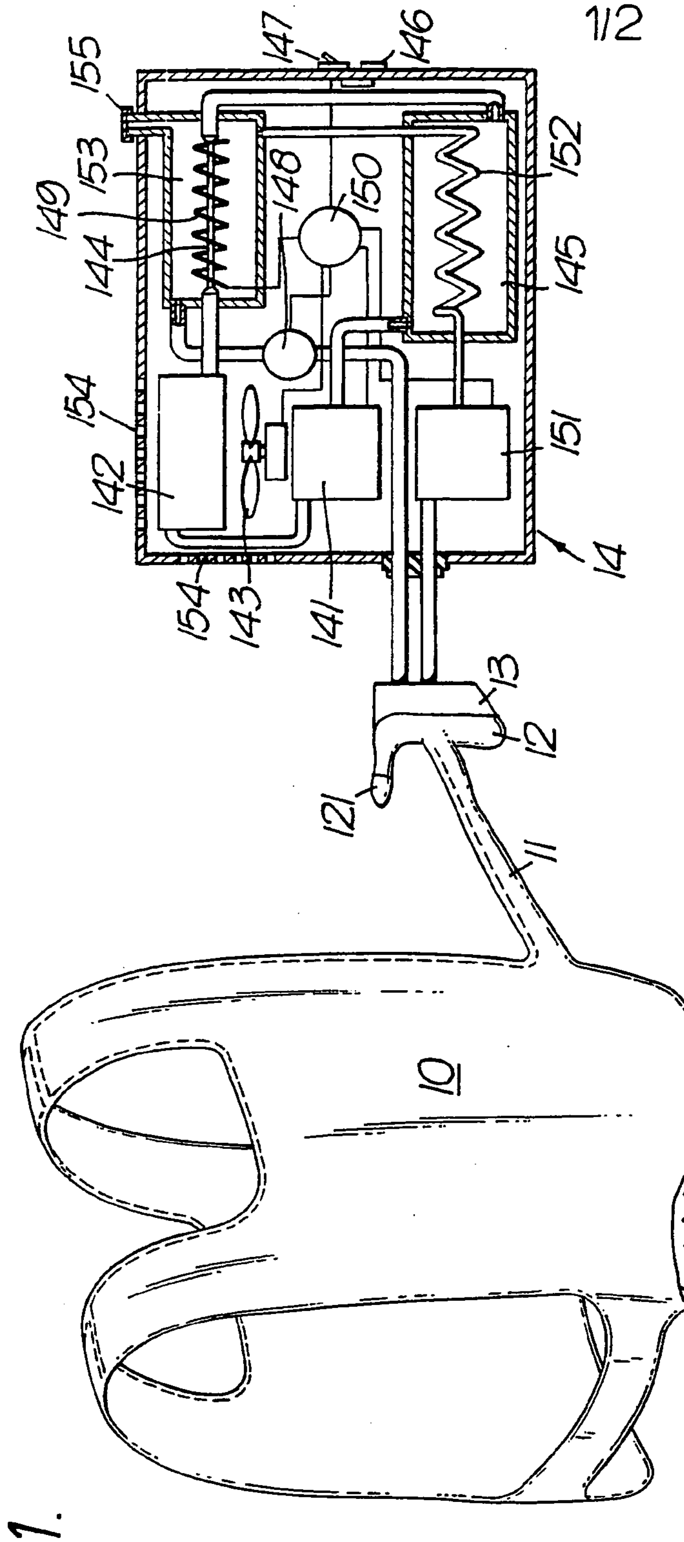


Fig.1.

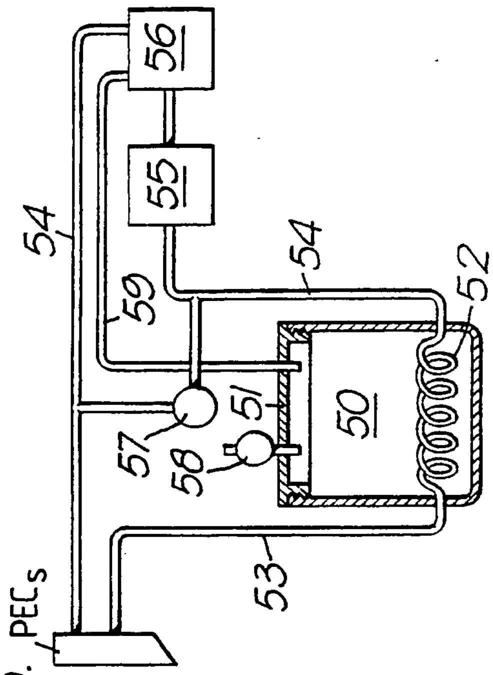


Fig.5.

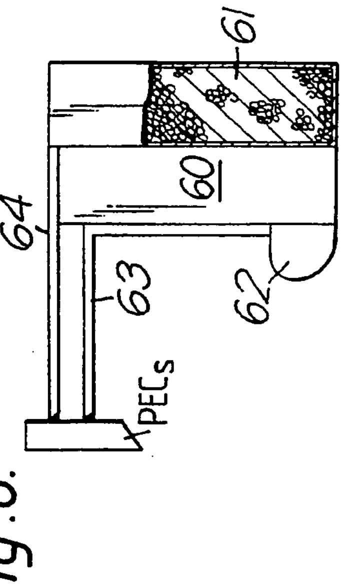


Fig.6.

Fig.2.

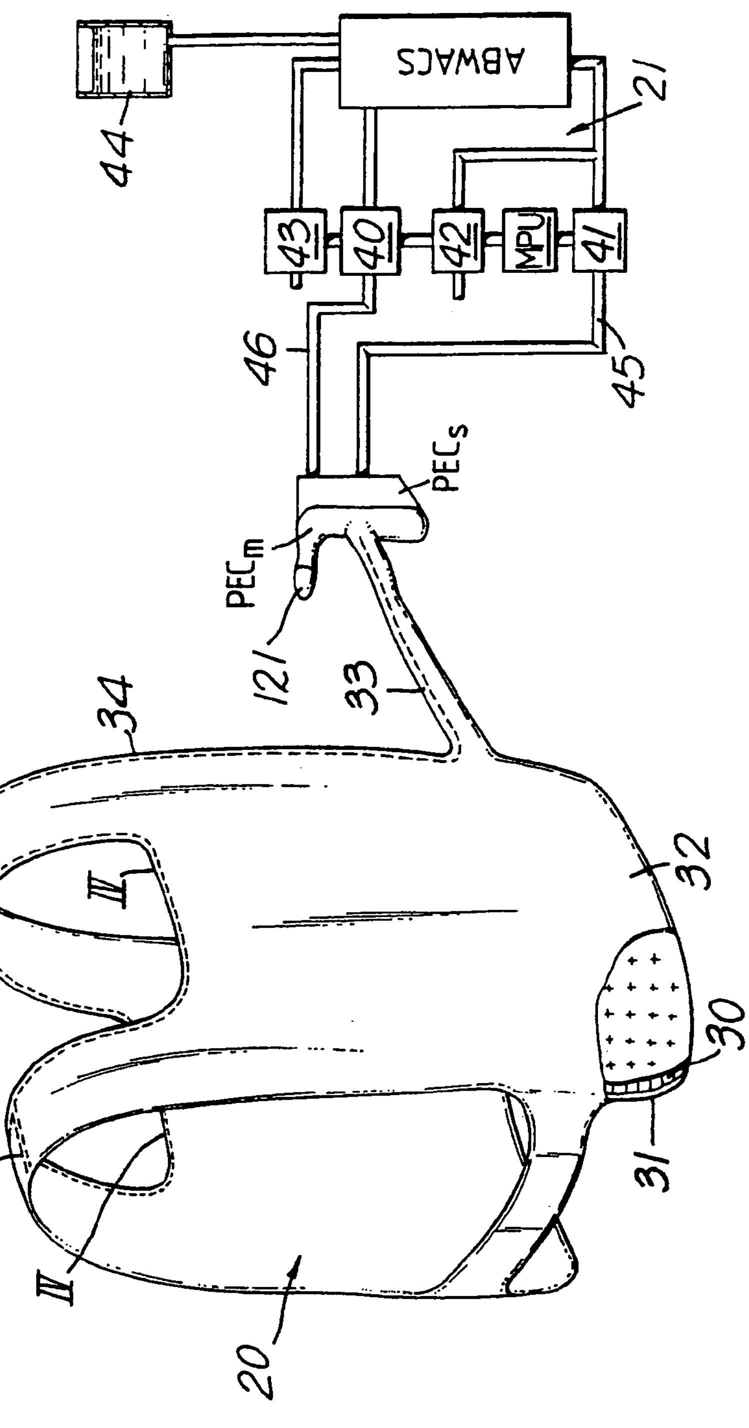


Fig.3.

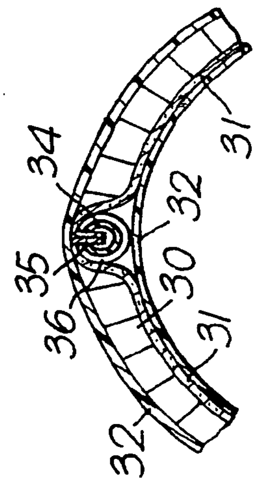
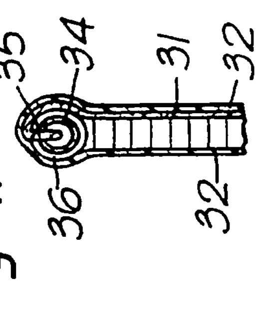


Fig.4.



SPECIFICATION

Improvements in heat pipes

The present invention relates to heat pipes, especially those constituted as thermal conditioning garment assemblies for personnel use. It is particularly concerned with the provision of thermal conditioning of finite duration in circumstances where mobility, minimum bulk, and/or non-linkage to permanent power supplies may be required.

In UK Patent Specification 8106782 there is described a flexible or conformable heat pipe assembly in sheet form suitable for use as a thermal conditioning garment, the assembly having a reticulated structure including wicking and void continua, an impermeable plastics film envelope surrounding the structure, and means by which the assembly may be outgassed and evacuated and liquid introduced thereinto.

According to the present invention a heat pipe assembly comprises a first heat exchanger of heat pipe construction for providing thermal conditioning to a person or apparatus, thermal reservoir means for servicing the first heat exchanger, a duct for liquid and a duct for vapour, the ducts connecting the first heat exchanger element and the thermal reservoir means, means for evacuating and maintaining evacuating the interior of the assembly, means for establishing and disestablishing communication between the first heat exchanger and the thermal reservoir means.

It will be appreciated that the thermal reservoir means may be a source of heat, a sink of heat, or a device, such as that described in UK Patent Specification 1550351, which is capable of both supplying heat and extracting heat, as required. That is to say that the same heat pipe assembly may, in some embodiments, be employed to put heat into or to take heat out of something or someone without structure modification.

In the event that the thermal reservoir means is a cold or hot body or something which is not to form part as such of the heat pipe fluid circuit, the reservoir means may include a heat exchanger, perhaps in heat pipe form, which does form part of the heat pipe fluid circuit, and a heat reservoir which does not, in which case the means for establishing and disestablishing the said communication may comprise means for placing and maintaining the reservoir heat exchanger in contact with the heat reservoir, e.g. straps, together perhaps with a connector connecting ducts together, or connecting ducts to the first heat exchanger, or to the reservoir heat exchanger.

At its simplest, therefore, the thermal reservoir may comprise a pack of ice or dry ice, perhaps in the portable cooler form described in UK Patent Specification 1376604, or of preheated liquid or mineral, or an externally powered heater or cooler. The combined heat source and sink mentioned above as described in UK Patent Specification 1550351 is also a candidate. Alternatively the thermal reservoir means may comprise a rechargeable supply of cooled liquid and a distant sink for vapour, incorporating for example molecular sieve material or zeolite, from which the vapour can subsequently be discharged. In another embodiment, described more fully in the copending UK Patent Application 8129023 the thermal reservoir means may comprise a heat pump, e.g. a compressor.

In the event that the thermal reservoir is to form part of the heat pipe fluid circuit the said communication establishing and disestablishing means may isolate the heat pipe fluid from the reservoir by means of a connector on the first heat exchanger, on the reservoir, or in the ducting intermediate the first heat exchanger and the reservoir. As it is usually important to the function of a heat pipe that it be substantially outgassed and maintained at low pressure, the connector in this case may include valve means for isolating the heat pump fluid from the environment while the said communication is not established.

The ducts for liquid and vapour may be constituted by one or more heat pipes, the void(s) forming the vapour duct and the wicking or its equivalent the liquid duct. If they are required to be flexible and/or light in weight, they may be constituted by the heat pipe ducting described in UK Patent Specification 8106782. Thus the ducting may comprise a flexible structure reticulated along the duct length and perhaps formed of woven plastics filament, flexible wicking extending along the duct length in some of the reticulation, and an impermeable plastics film enveloping the structure where, however, remoteness, weight and bulk minimisation, and/or required liquid feed rate demand it the ducts may comprise simple tubes. The assembly may include pump means for pumping liquid through the assembly, or for establishing and maintaining a low pressure within the assembly, or both. In the event that the assembly is intended both to pump heat into or to take heat out of something or someone sensor means may be included for instructing the pump which way to direct the liquid.

The first heat exchanger may be a sheet heat pipe comprising a reticulated structure having wicking and void continua in breadth and length. It may further be flexible, with the reticulated structure perhaps being formed of woven plastics filament and the envelope comprising impermeable plastics film. According to a feature of the invention it may be in thermal conditioning undergarment form, preferably constructed as a poncho, and may thus be as described in UK Patent Specification 8106782. If the first heat exchanger is to be used for substantially exclusively for the removal of heat from something or someone it may additionally incorporate the liquid sprinkler means described in copending UK Patent Application 8129024.

In a principal embodiment of the invention a heat pipe assembly, suitable for use by aircrew, comprises a first heat exchanger in the form of a

thermal conditioning undergarment comprising a flexible reticulated structure incorporating wicking and void continua extending substantially throughout the area thereof and enveloped in impermeable plastics film, liquid and vapour ducting connecting the garment via a seat mounted connector and pump means with a thermal reservoir, the connector being operable while disconnected to isolate the garment interior from its environment, and the pump being operable both substantially to evacuate the assembly and to pump the liquid. The thermal reservoir may be permanently aircraft mounted, but in one alternative to the above principal embodiment the reservoir is, like those described in UK Patent Specification 1376604 and 1550351, portable and stowable in the aircraft, and the connectors are adapted to cater both for reservoir exchange and emergency egress from the aircraft.

Similar assemblies might be constructed for use in industrial contexts, when the connectors might merely permit exchange of reservoirs, and the reservoirs might be either mobile or portable. The ducting in such circumstances might be lagged.

Heat pipe assemblies in accordance with the invention will now be described by way of example, with reference to the accompanying drawings, of which:

Figure 1 illustrates a thermal conditioning garment assembly with one form of thermal reservoir assembly.

Figure 2 illustrates an alternative garment assembly.

Figure 3 is a section detail at III in Figure 2, and

Figure 4 is a section detail at IV in Figure 2.

Figure 5 illustrates an alternative thermal reservoir.

Figure 6 illustrates a further thermal reservoir.

The assembly illustrated in Figure 1 comprises a thermal conditioning undergarment 10 having an associated fluid duct 11, a heat exchange interchange in which a heat pipe heat exchanger 12 is maintained in thermal contact with a control exchanger 13, and a thermal reservoir 14.

The garment 10 is of poncho form and comprises a flexible reticulated structure 101, a wick 102 coextensive with the inner face of the structure 101, and an impermeable metallised plastics film 103 enveloping the structure 101. The structure 101 includes a void continuum which is also coextensive with the inner face of the garment.

The duct 11 comprises a flexible reticulated structure the reticulations whereof extend along the duct only, some being occupied by wicks communicating with the wick 102 and some being void, the voids being in communication with those in the structure 101, and an envelope similar to and continuous with the envelope 103.

The heat exchanger 12 is in heat pipe form with its wick contiguous with the ducting wick and in thermal contact with the heat exchanger 13, and its void continuous with those in the duct 11. The heat exchanger 12 includes a valve 121 for outgassing, evacuating and maintaining evacuated the garment interior.

The thermal reservoir 14 is as described in UK Patent Specification 1550351. It includes refrigeration means, thermal control means, and fluid supply means. The refrigerator means comprises a compressor 141, a condensor 142 with a fan 143, a capillary 144 and an evaporator 145. The refrigerator means is charged with a refrigerant such as Refrigerant 12 (dichlorodifluoromethane). The temperature control means comprises a supply socket 145, and on/off switch 147, a temperature transducer 148, and a heating element 149, all of which are electrically connected to a manual temperature control 150. The fluid supply means comprises a pump 151, a heat exchanger 152 in the evaporator 145, and a heat exchanger 153 associated with the heating element 149, and the capillary 144. The case of the reservoir has perforations 154 in the region of the fan 143, for allowing the fan to pass environmental air over the condenser 142. The heat exchanger 153 acts also as a reservoir for the fluid circuit and has a filler cap 155 on the casing. The temperature control 150 controls the compressor 141, the pump 151, and the heating element 149 in response to signals from the temperature transducer 148. The fan 143 is driven by the compressor 141.

The unit is prepared for use by connecting the heat exchanger connector 13 into the fluid circuit, filling the fluid circuit at 155 with a liquid such as water glycol, and by connecting the pack to a suitable electricity supply.

The garment 10 is prepared for use by evacuation, back filling with water, and outgassing at valve 121. When it has been donned, with the umbilical 11, emerging from the user's outer clothes, the heat exchangers 12 and 13 are mated.

To operate the unit it is switched on at 147, when the pump 151 circulates liquid in the liquid supply through the heat exchangers 152 and 153 and 13 in that order. Using the control 150 the user selects the temperature he requires.

If the selected temperature of the liquid is below that presently sensed at 148, the compressor 141 is switched on by the temperature control and the heating element 149 is switched off. The compressor takes refrigerant vapour from the evaporator 145, compresses it, and passes it to the condensor 142. Liquid refrigerant from the condenser passes to the capillary 144, and thence to the evaporator 145. In the evaporator the refrigerant removes heat from the liquid in the heat exchanger 152. The chilled liquid then passes through the heat exchanger 153, wherein by cooling the capillary 144 it assists the flow of refrigerant therethrough and thus increases the amount of cooling.

For much of the available cooling temperature range, control of the coolant temperature is augmented by the variation of environment

temperature to the condenser 142. The higher the environment temperature, the greater the pressure in the condenser and hence of the liquid refrigerant in the capillary, and the greater the cooling available in the evaporator.

If the selected liquid temperature is slightly higher than the sensed temperature the heating element 149 will be switched on. This warms both the liquid in the heat exchanger 153 and the refrigerant in the capillary 144. The latter becomes superheated and due to the formation of vapour bubbles therein flow through the capillary is restricted and less cooling becomes available in the evaporator 145. At the same time the liquid in the liquid supply is being warmed at 153 to the selected temperature.

If a considerably high liquid temperature is required the compressor 141 is switched off and the heat of the liquid is modified solely by the heating element 149. The output of the heater is controlled by the temperature difference between sensed and required temperature. Typically the heater may be off when the temperature selected is below 30°C and the compressor off when the temperature selected is above 35°C.

Such a pack can measure about 8 cm×12 cm×26 cm and weigh about 5 kg. Using a 3-phase 400 Hz aircraft supply it can provide 200 watts of heating at 0°C to 300 watts cooling at 55°C, with 200 watts of cooling being available at temperatures above 55°C up to 65°C. It is thus particularly suitable for use by aircrew in aircraft cockpits in extreme climates, when the small size of the pack should permit it to be stowed in the cockpit.

The alternative garment assembly illustrated in figures 2—4 comprises a flexible heat pipe undergarment 20 as described in copending UK Patent Application 8129024, a thermal reservoir 21 as described in copending UK Patent Application 8129023, and connector means PECm and PECs.

The garment 20 is a poncho style undergarment shaped to overlie the shoulders of a person. It comprises a woven plastics structure 30 supporting at its working face a perforated wick 31 and surrounded by a non-rigid, impermeable plastics envelope 32. The structure 30 provides a continuous void behind the wick extending throughout the garment. The garment carries an umbilical heat transfer lead 33 leading to the connector PECm. The garment is therefore substantially similar in construction to that described in UK Patent Specification 8106782. It is, however, constructed as a heat receiver element, so that the umbilical lead 33 is arranged for the conveyance of cool liquid to and vapour from the garment. Thus the garment and lead 33 contain liquid distribution means in the form of a flexible plastics tube 34 leading from the lead 33 up one side of the garment, across the shoulders and around the neck of the garment. Across the shoulders, i.e. in the region III (see Figure 3), and across the neck front and back, i.e. in region (see Figure 4) the tube 34 is slit in a substantially uppermost location. Edges 35 of the wick 31 are held in the slits by thread 36 sewn through the wicks and passed around the tube 34.

The garment 20 as such is outgassed, and evacuated prior to use, the PECm having an isolating valve 121 preventing environmental ingress when disconnected.

The thermal reservoir 21 comprises a liquid pump 40, a motor MPU, a compressor 41, an evacuator 42, an air blower pump 43, a heat sink ABWACS, and a liquid reservoir 44 therefore the thermal reservoir 21 being connected to the connector PEC by a vapour duct 45 and a liquid duct 46. The duct 45 is adapted to convey vapour from the connector PECs to the compressor 41, and the duct 46 to convey liquid from the pump 40 to the PECs. The compressor 41 is arranged to supply the heat sink ABWACS which in turn is arranged to supply the pump 40. The motor MPU is arranged to drive the pump 40, the compressor 41, evacuator 42 and the blower 43, the evacuator 42 being arranged to evacuate the assembly prior to use and to be operated occasionally, to outgas the assembly and maintain the low pressure. The connector PECs, like that PECm, has an isolating valve preventing environmental ingress when disconnected.

With both the garment and the thermal reservoirs separately evacuated and charged and then the connectors PECm and PECs mated to establish a fluid cycle, the pump and compressor may be initially required to modulate the interior pressure before use of the assembly as such commences.

In operation of the garment assembly to cool a wearer, the pump 40 pumps liquid from the sink ABWACS along the duct 46, through the connector PECs and PECm and the lead 33 to the liquid distributors 34. At stations III and IV the liquid is absorbed into the wick 31 and is distributed therethrough. The liquid is vaporised by heat from the body and the vapour is conveyed via the said continuum in the structure 30 and the leads 33 and 45 to the compressor 41, where it is condensed and the liquid returned to the sink ABWACS. In the heat sink ABWACS condensation and cooling of the working fluid is effected by enforced evaporation from a distinct felt supplied with liquid from the reservoir 44 and blown air from the blower 43.

It will be appreciated that the total amount of liquid employed within the assembly may require to be predetermined for a given wick and heat pipe capacity and expected temperature range. The garment may, therefore, be stored, supplied and donned dry, with the required liquid and in the heat sink ABWACS.

It will also be appreciated that the assembly described with reference to Figure 2 operates to cool a wearer only, and cannot function to supply warmth. The same is true of this assembly when either of the thermal reservoirs illustrated in Figures 5 and 6 are substituted for the reservoir 21.

The thermal reservoir illustrated in Figure 5 is

substantially that described in UK Patent Specification 1376604. It comprises a pressure vessel 50 with a tight-fitting screw-on cap 51. A coil 52 at the bottom of the vessel, has an inlet end connected by a pipe 53 to a connector PECs and an outlet end connected by a pipe 54, via a liquid reservoir and air trap 55 and a pump 56 to the connector PECs.

An adjustable valve 57 is connected across the pipe 54 upstream of the reservoir 55 and downstream of the pump 56.

The vessel has a relief valve 58, set to a pressure of about 80 psia, in the cap 51 thereof, while a pipe 59 connected to the cap 51 communicates the interior of the vessel with the pump 56. As with embodiments described above the pump is arranged initially to evacuate the assembly.

For operation, the reservoir 55 is primed with a suitable coolant liquid, such as dimethyl silicone, and with the cap 51, the vessel 50 is filled with solid carbon dioxide, and the cap 51 tightly replaced.

When the vessels are subjected to environmental heat the pressure therein will rise and carbon dioxide gas will pass through the pipe 59 to drive the pump 56. The pump 56 then pumps the coolant liquid via the pipe 54 and the connector PECs and PECm to the garment 20.

When the pressure in the vessel 50 reaches the triple point pressure of carbon dioxide, about 75 psia, liquid carbon dioxide will start to form, and this will settle to the bottom of the vessel and surround the coil 56. Vapour passing through the coil 52 from the garment 20 via the pipe 53 will then be condensed and pass as liquid to the reservoir 55.

A stage will be reached when all the solid carbon dioxide has disappeared, leaving only the liquid and gaseous phases. Provided that the coil 52 is immersed in liquid the cooling unit will still operate efficiently, but the pressure in the vessel 50 will rise and some carbon dioxide gas may escape through the relief valve 58.

Temperature control of the garment 20 can be effected by adjustment of the valve 57 to vary the volume of liquid by-passing the garment.

The thermal reservoir illustrated in Figure 6 comprises a liquid source 60 and a distinct vapour sink 61. The liquid source 60 is connected via a pump 62 and a duct 63 with the connector PECs, which is also connected via a vapour duct 64 with the sink 61. The source 60 is charged with a suitable quantity of water, and the sink 61 is filled with dried zeolite.

After assembly and evaluation as with the apparatus described above with reference to Figures 2 to 5, in operation of the assembly water is supplied by the pump from the source 60 to the garment 20 via the connectors PEC and the ducts 33, 34 and 63, and vapour from the garment passes via the tube 64 and is absorbed in the zeolite in the sink 61.

The expression "PEC" employed to indicate the connector in Figures 2, 5 and 6, is that normally used to describe the connector means on an ejector seat by which various services, e.g. oxygen and intercom, are conveyed to an aircrewman. The PEC, which stands for Personal Equipment Connector, may have three parts; the aircraft connector, the seat mounted element, and the aircrewman connector, arranged so that the aircraft/seat connection is separated upon ejection and the seat element arranged to convey oxygen to the aircrewman from a seat mounted source until seat/man (aircrewman/seat element) separation. There may not be a need to condition thermally an aircrewman during that stage of an ejection that a man is attached to his seat, but the triple connector may readily be arranged not just as a normal connector/interchange heat exchanger for the thermal conditioning means of the present invention but in addition to allow or prevent as required during the said man/seat attachment stage of an ejection, normalisation of the pressure within the thermal conditioning garment to restrict the flow of body heat to the seat for example.

Of course the first heat exchanger need not be a garment and need not be for personal thermal conditioning, and as a garment need not be exclusively for aircrew use, certainly not only those in ejector seats. An advantage of apparatus such as that described with reference to Figures 5 or 6 is that it does not require an external power source, and can be portable to a place of work so as to permit an operative to work in a hot environment for periods larger than he would otherwise have been able.

Claims

1. A heat pipe assembly comprising a first heat exchanger of heat pipe construction for providing thermal conditioning to a person or apparatus, thermal reservoir means for servicing the first heat exchanger, a duct for liquid and a duct for vapour, the ducts connecting the first heat exchanger element and the thermal reservoir means, means for evacuating and maintaining evacuating the interior of the assembly, means for establishing and disestablishing communication between the first heat exchanger and the thermal reservoir means.

2. A heat pipe assembly as claimed in claim 1 and wherein the means for establishing and disestablishing the said communication comprises means for placing and maintaining the reservoir heat exchanger in contact with the heat reservoir with a connector connecting ducts together, or connecting ducts to the first heat exchanger or to the reservoir heat exchanger.

3. A heat pipe assembly as claimed in claim 1 or claim 2 and wherein the thermal reservoir comprises a pack of ice.

4. A heat pipe assembly as claimed in claim 1 or claim 2 and wherein the thermal reservoir means comprises a rechargeable supply of cooled liquid and a distinct sink for vapour.

5. A heat pipe assembly as claimed in claim 4 and wherein the vapour sink incorporates a

molecular sieve material from which the vapour can subsequently be discharged.

6. A heat pipe assembly as claimed in claim 1 and wherein the means for establishing and disestablishing the said communication comprises a connector on the first heat exchanger, on the reservoir, or in the ducting intermediate the first heat exchanger and the reservoir.

7. A heat pipe assembly as claimed in claim 6 and wherein the connector includes valve means for isolating the heat pump fluid from the environment while the said communication is not established.

8. A heat pipe assembly as claimed in any one of the preceding claims and wherein the ducts for liquid and vapour and constituted by one or more heat pipes, the void(s) forming the vapour duct and the wicking or its equivalent the liquid duct.

9. A heat pipe assembly as claimed in any one of the preceding claims and wherein the first heat exchanger is sheet heat pipe comprising a reticulated structure having wicking and void continua in breadth and length.

10. A heat pipe assembly as claimed in claim 9 and wherein the first heat exchanger is conformable.

11. A heat pipe assembly as claimed in claim 9 or claim 10 and wherein the first heat exchanger is a thermal conditioning garment.

12. A heat pipe assembly, suitable for use by aircrew and comprising a first heat exchanger in the form of a thermal conditioning undergarment comprising a flexible reticulated structure incorporating wicking and void continua extending substantially throughout the area thereof and enveloped in impermeable plastic film, liquid and vapour ducting connecting the garment via a seat mounted connector and pump means with a thermal reservoir; the connector being operable while disconnected to isolate the garment interior from its environment, and the pump being operable both substantially to evacuate the assembly and to pump the liquid.

13. A heat pipe assembly substantially as hereinbefore described with reference to the accompanying drawings.

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